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ALBERTA DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH

WATER DIVERSION PROPOSALS OF NORTH AMERICA

PREPARED FOR

CANADIAN COUNCIL OF RESOURCE MINISTERS

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WATER DIVERSION PROPOSALS OF NORTH AMERICA

Submitted by:

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December, 1968
Revised March, 1969



ALBERTA DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION

R.E. BAILEY
DIRECTOR

TABLE OF CONTENTS

PAGE

Introduction 1

NAWAPA
North American Water and Power Alliance 2

Western States Water Augmentation Concept 11

Canadian Water Export 19

The GRAND Canal Concept 25

The Central North American Water Project 30

Proposed Great Lakes - Pacific Waterways Plan 34

The Magnum Canal 37

Summary 40

References

Map Appendix

NAWAPA

Western States Water Augmentation Concept

The Kuiper Scheme
(Canadian Water Export)

The Kierans Scheme
(The GRANDE Canal Concept)

CeNAWP
(The Central North American Water Project)

The Decker Scheme
(Proposed Great Lakes - Pacific Waterways Plan)

The Magnum Scheme
(The Magnum Canal)

"WATER. The nation's total demand for fresh water is expected to keep growing at a rate at least equal to that of population. Irrigation withdrawals may increase by half by the year 2000; municipal use may double and manufacturing use quadruple. There is no prospect of water shortage on a nation-wide scale.

In the Eastern U.S.A. severe pollution of water supplies will be the main problem. Accelerated programs for treatment of sewage as well as increased upstream storage are required.

In the Western U.S.A. water is scarce in many areas and in the future the economic priority of irrigation may take second place to industry and municipal supplies. More storage dams and long distance transmission of water will be required." [1]

The above excerpt illustrates one of the problems which is attracting increasing attention today. Various solutions to the problem of water distribution have already been proposed. Summaries of several of these proposals are presented below.

[1] "Resources in America's Future: Patterns of Requirements and Availabilities, 1960 - 2000", Resources for the future.

NAWAPA

North American Water and Power Alliance

Proposed by the Ralph M. Parsons Company,

Los Angeles and New York.

The NAWAPA proposal is a continental concept designed to fulfill a continental need. The authors suggest that the proposal would provide North America with water in sufficient quantities to assure adequate water supplies for many generations to come.

THE PROBLEM

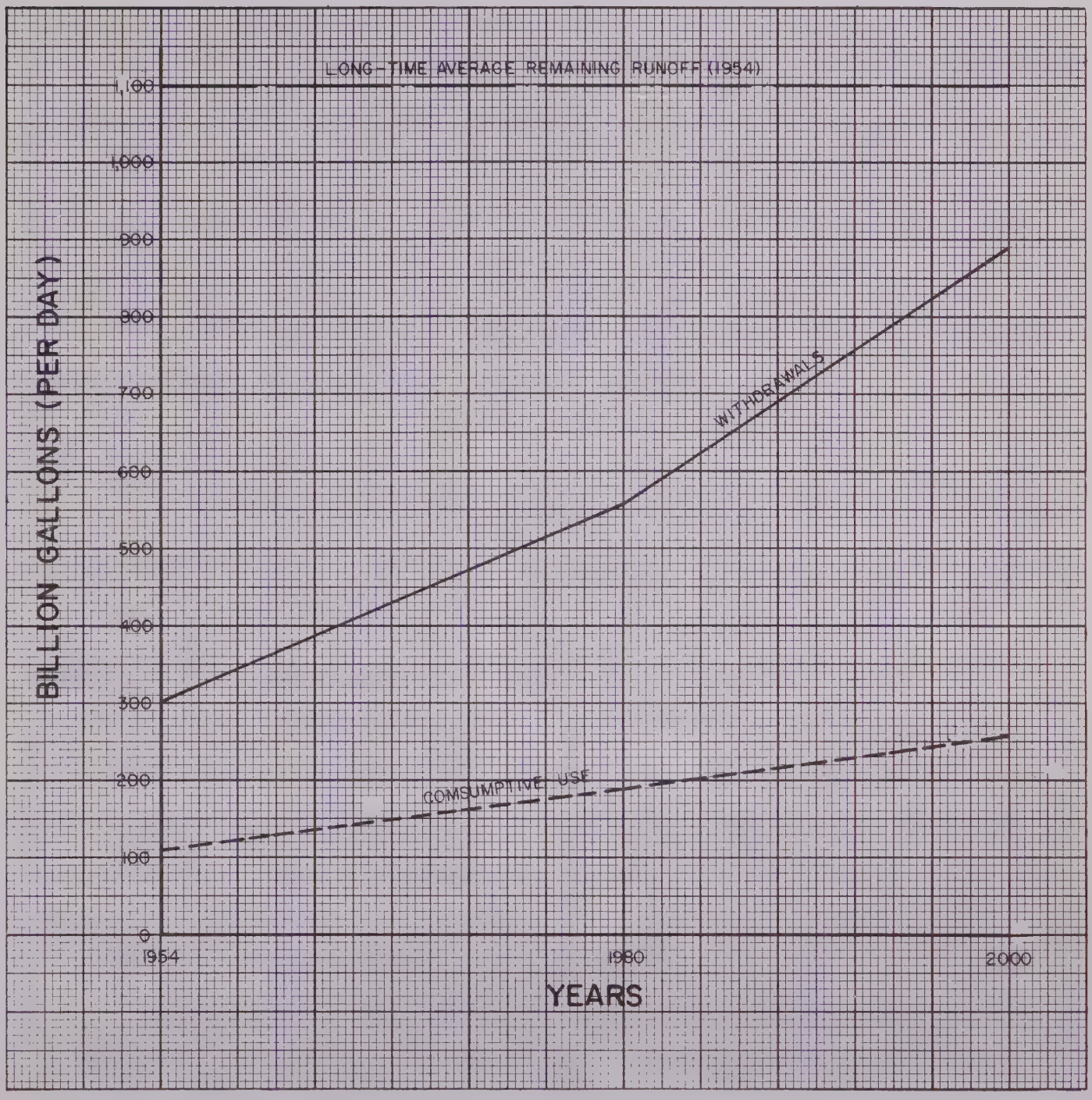
The NAWAPA proposal would redistribute surplus water from high precipitation - low utilization areas to low precipitation - high utilization areas. In certain regions of the continent, water is wasting into the seas, while in other regions, water is becoming a critical factor for future expansion.

PREDICTED TRENDS AND NEEDS

The NAWAPA proposal outlines certain trends and projections, to demonstrate the need for water transfer.

GRAPH I

PREDICTED WATER REQUIREMENTS FOR THE UNITED STATES



Graph I illustrates the predicted water requirements for the United States by the year 2,000. The same source estimates that the total water required by 2,000 A.D. will equal 699.6 billion gallons per day, from a total long-time average remaining runoff (1954) of 1,100 billion gallons per day. The concern expressed by the Western States can be better appreciated when the figures for that area are totaled. The Western water resource region, including the Pacific Northwest, had, in 1954, a long-time average remaining runoff of 197.3 billion gallons per day, while by the year 2,000, projected withdrawals will equal 212.2 billion gallons per day.

The present population of the Western States is in excess of 43 million and is expected to reach 108 million by 2,000 A.D.

THE NAWAPA PROPOSAL

This proposal would involve water control projects in areas with a total drainage area of approximately 1.3 million square miles, and with an estimated average annual runoff of 663 million acre-feet of water. Of this total, about 110 million acre-feet, or less than 20% of the total flows of the basins would be withdrawn for irrigation, industrial, and municipal uses. The cornerstone of the NAWAPA plan is a 500 mile long storage reservoir in the Rocky Mountain Trench of interior British Columbia. Key elements of the NAWAPA proposal are outlined below, by regions.

The Yukon Territory and Alaska

The headwaters of the Yukon and Tanana Rivers would be dammed to form a reservoir. In addition, the Copper River would be dammed, and diverted to this reservoir by means of a tunnel. The water so collected would be pump-lifted 300 feet into the existing Peace River Reservoir.

British Columbia

Part of the water from the Peace River Reservoir would be diverted into the proposed Alberta-Great Lakes Canal. Some 30,000 c.f.s. would be pump-lifted 670 feet from the reservoir into the Rocky Mountain Trench. The head-waters of the Columbia, Fraser, and Kootenay Rivers would be dammed to form a 500 mile long reservoir extending to the vicinity of Flathead Lake in Montana.

Water from the Upper Fraser River would be fed into the Columbia above Revelstoke for maximum firm power generation on the Columbia. The average annual yield into the Trench would average 74 million acre-feet and would be the principal supply for the NAWAPA system.

Alberta

The Alberta-Great Lakes Waterway would originate in Alberta. This would require damming and diversion of the Peace River, the Smoky River, Lesser Slave Lake, the Athabasca River, and the North Saskatchewan River. The diverted water would be conveyed by constructed canal.

Saskatchewan

The Waterway would continue across Saskatchewan, via the Qu'Appelle River and the proposed Moose Jaw Canal. Water would also be diverted into the Missouri River via the proposed Williston Canal, and into the Mississippi River via the proposed Dakota Canal.

Manitoba

The Waterway would incorporate Lake Winnipeg into the system. As well, a Hudson Bay Seaway would be developed from Lake Winnipeg via the Nelson River.

Ontario

The Alberta-Great Lakes Waterway would terminate in Lake Superior. Also, the James Bay Seaway would be developed from James Bay to Lake Huron.

Quebec

The Knob Lake Barge Canal would connect Northern Quebec with the James Bay Seaway.

United States

Via an elaborate system of canals, tunnels, and aqueducts, water would be distributed to Idaho, Oregon, Utah, Nevada, California, Arizona, New Mexico, Texas, Colorado, Kansas, Nebraska, and Oklahoma.

Mexico

Water would be distributed to the States of Baja California, Chihuahua, and Sonora.

Costs of NAWAPA

Cost estimates vary from $80 to $100 billion, and the implementation period from 20 to 30 years.

TABLE I

ESTIMATED EXPENDITURES

COUNTRY	RESERVOIRS	IRRIGATION SYSTEMS	NAVIGATION
Canada	$16,223,840,000	$15,030,000,000	$340,000,000
United States	$21,657,980,000	$24,677,000,000	Included under irrigation
Mexico		$ 2,071,180,000	
SUBTOTALS	$37,881,820,000	$41,778,180,000	$340,000,000
	TOTAL	$80,000,000,000	

Source: Western Water Development

TABLE II

ESTIMATED EXPENDITURES

ITEM	COST IN U.S. DOLLARS
Land Acquisition & Relocation	$ 16,600,000,000
Engineering	$ 8,900,000,000
Construction	$ 64,500,000,000
Contingencies	$ 10,000,000,000
TOTAL	$ 100,000,000,000

Source: North America Water and Power Alliance

Benefits from NAWAPA

Canada:

1) would receive 22 million acre-feet of water annually for industrial, municipal, and agricultural use.

2) would generate 30 million KW for outside sale plus 30 million KW for sale to the NAWAPA system.

3) would receive $2 billion annually from the sale of power and water, shipping tolls, etc.

4) would be provided with cheap water transport.

5) would receive an inflow of at least 40 million acre-feet per year into Lake Superior.

6) would achieve control of lake levels on the Great Lakes, plus increased hydro power production on the Niagara.

7) could control, stabilize, and lower Lake Winnipeg.

8) could irrigate 9 million acres of land.

9) would increase annual national income from agriculture, livestock, mining, and manufacturing by approximately $9 billion annually.

10) would receive $2 to $3 billion annually from investment and expenditure during the construction period.

The United States:

1) would receive 78 million acre-feet of water annually.

2) would make available for sale 38 million KW.

3) would have a north-south seaway from Alaska to Northern Montana.

4) could irrigate 21 million acres of land.

5) would receive $3 to $4 billion annually during the construction period.

6) would increase the annual national income by approximately $30 billion.

Mexico:

1) would receive 20 million acre-feet annually.

2) would receive 2 million KW of power annually.

3) could irrigate 5,940,000 acres.

ALTERNATIVES

The publication Western Water Development inventoried existing plans and proposals for dams, power projects, canals, flood control and other relevant studies in the United States. A total of over 3,000 projects for development of water resources of the Western United States alone have been considered. These projects have an estimated cost of approximately $60 billion, and would provide 2.8 billion acre-feet of stored water. The NAWAPA concept has a total of 369 projects, would cost about $80 billion, and would provide in excess of 4 billion acre-feet of stored water.

OBSERVATIONS AND COMMENTS

Canada provides the greater amount of the total flows and most of the storage area.

Possible effects on the Rocky Mountain Trench can be summarized as follows:

a) several thousand acres of arable land, plus mineral and forest potential would be flooded. As well, several communities would be drowned. For example: the proposed F.S.L. of the reservoir is 3,000 feet; Radium Hot Springs lies at an elevation of 2,658 feet above sea level.

b) all major east-west and north-south ground transportation systems in British Columbia would be disrupted.

c) the structural stability of the Rocky Mountain Trench, if loading of the magnitude envisioned were completed, has been questioned.

The effect on regional climates of transferring large volumes of cold water southward into hot, arid areas is unknown.

IMPLEMENTATION PROBLEMS

Agreements for the sharing of interprovincial waters would have to be arrived at.

Agreements for the sharing of international waters would have to be arrived at.

The problems involved with eventual recall of exported water would have to be negotiated.

Sources: Western Water Development compiled by the Special Subcommittee on the Western Water Development of the Committee on Public Works, United States Senate.

Sources: Continued

NAWAPA, North American Water and Power Alliance Brochure 606-2934-19 compiled by the Ralph M. Parsons Company; Los Angeles and New York.

North American Water & Power Alliance - NAWAPA Roland P. Kelly, Third Annual American Water Resources Conference.

WESTERN STATES WATER AUGMENTATION CONCEPT

by

Lewis Gordy Smith, P. Eng.

As indicated by the title "Western States Water Augmentation Concept" this proposal is concerned principally with that area lying west of the Mississippi River.

THE PROBLEM

1) There is a growing water shortage in the western United States.

2) The western states are now quarreling over water supplies which will, in the near future, prove to be inadequate at any rate.

3) It is important to create work opportunities as an alternative to rising welfare handouts.

4) Existing cities are becoming over-crowded, but few alternative building sites could be developed in the West because of water restraints.

PREDICTED TRENDS AND NEEDS

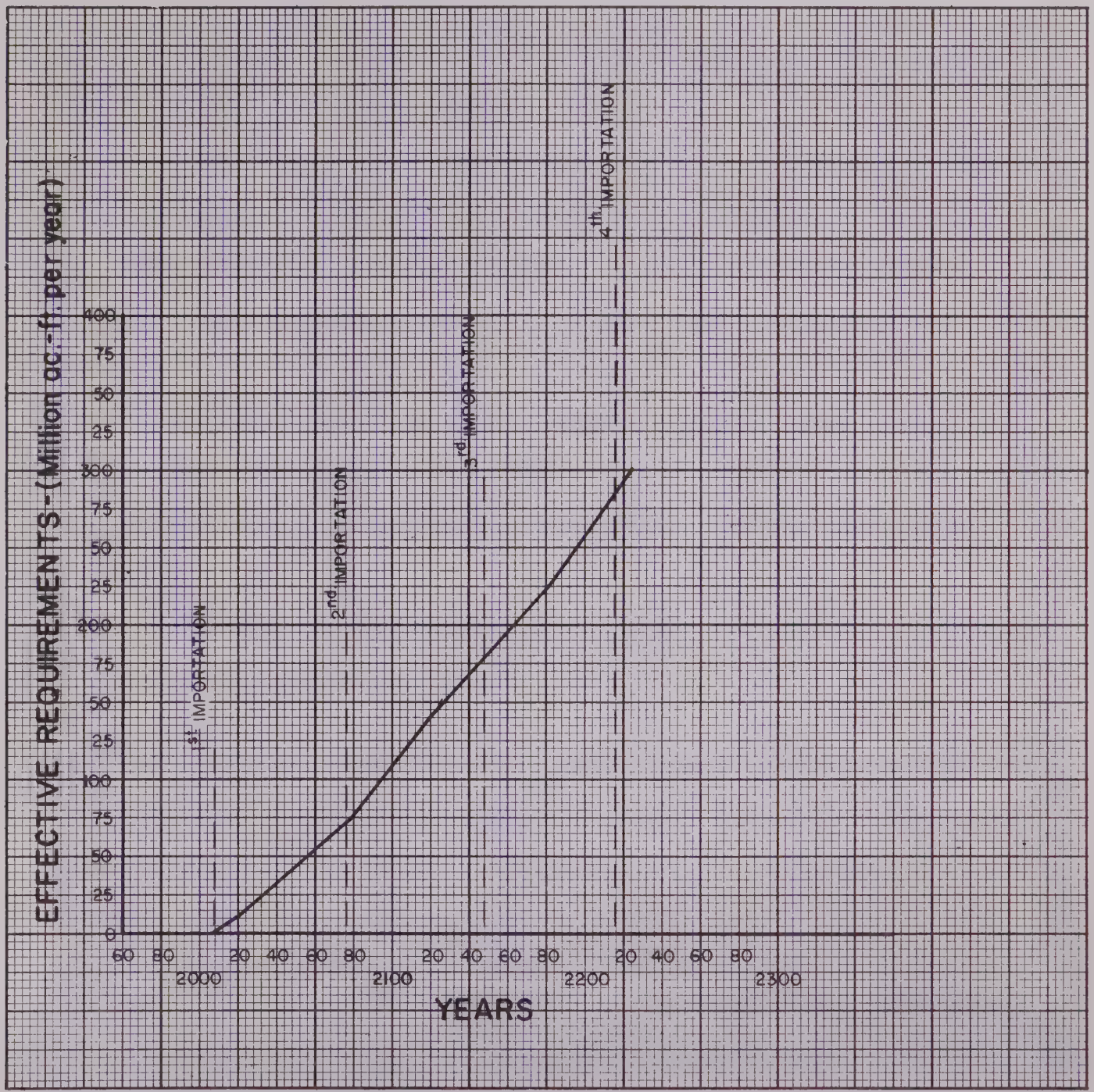
1) The per capita water use in the United States in 1965 is estimated at 1,900 gallons (U.S.) per day. This includes all water consumed for food production, manufacturing, etc. Nineteen hundred gallons per day is equal to 2.16 acre-feet per person per year. The rate is predicted to drop to 1.1 acre-feet by the year 2,000 and to 0.5 acre-feet by 2,200, with increasing efficiencies of water use.

2) Graph II shows the projected effective water requirements for the fourteen western states.

NOTE: Effective water use takes into account the factor of water reuse. To arrive at actual values for water to be supplied from new sources, divide by 1.98.

GRAPH II

WATER REQUIREMENTS OF STATES NEEDING TO IMPORT



Source: Western States Water Augmentation Concept

THE PROPOSAL

The flow of the Liard River, and a portion of the flow of the Mackenzie River near the mouth of the Liard would be reversed by means of a series of dams and pumping plants.

Water would be placed in the Rocky Mountain Trench via the Kichika River, a tributary of the Liard, and the Finlay River, a tributary of the Peace.

Water would be lifted from the Peace River into the Fraser River.

There are three suggested routes for conveying water through the Trench:

a) down the Fraser River then through a diversion tunnel under the Cascades into the Columbia River.

b) reversing a section of the Fraser River, then into the Columbia River.

c) reversing both the Fraser and the Columbia Rivers within the Trench, thence into the Kootenay River.

With routes "a" and "b" water would be passed through the Columbia River to the mouth of the Snake River in Washington State. Flows in the Lower Snake would be reversed to the mouth of the Salmon River; the Salmon River would be reversed to the Lemni Valley in Idaho.

With route "c" water would be transferred to the Salmon River by means of a series of canals and natural channels, several of which would be reversed, then pump-lifted to the Lemni Valley.

From the Lemni Valley, water would be diverted by tunnel under the Continental Divide into the Centennial Valley, in Montana. The proposed Centennial Valley Reservoir could provide approximately 50 million acre-feet of storage.

By means of a series of canals, tunnels, aqueducts, and natural channels, water would be distributed to Idaho, western Nevada, southern California, western Utah, Colorado, Arizona, Wyoming, Nebraska, Kansas, Oklahoma, Texas, and New Mexico.

Recent additions to the proposal include the Prairie Water Exchange Concept, (Sept.,1968). Major features of this concept include:

1) Diversion of the Smoky River into the Athabasca River via Lesser Slave Lake.

2) Upstream diversion of the Athabasca River into the North Saskatchewan River via the McLeod and Pembina Rivers.

3) Downstream diversion of the Athabasca River into the North Saskatchewan River by means of a canal.

4) Diversion of the North Saskatchewan River near Rocky Mountain House into the Red Deer River System.

5) Diversion of the North Saskatchewan River into the South Saskatchewan River via a canal.

6) Three diversions from the South Saskatchewan River: one from Alberta via canal to the Souris River; one via the Qu'Appelle River; and one via canal from Saskatchewan to the Qu'Appelle River.

Costs, Excluding the Prairie Water Exchange Concept.

A rough estimate of the capital cost of the primary collection and distribution system, expressed in 1967 United States dollars, is approximately $75 billion. This system would deliver 38 million acre-feet annually.

TABLE III

ESTIMATED CAPITAL COSTS

Collection and conveyance to Centennial Valley	$ 12 billion
Primary distribution system	$ 26 billion
Primary energy-generating facilities	$ 12 billion
Secondary distribution system	$ 25 billion
	$ 75 billion

Benefits, Excluding the Prairie Water Exchange Concept.

Canada:

1) would receive revenues from the sale of water and power.

2) would benefit from the $5 billion invested during the 30 year construction period.

3) could arrange provision for leasing arable areas in southern Arizona to provide warm climate agricultural lands for Canada.

The United States:

1) could supply water short areas, where water is becoming the limiting factor in further expansion, including the High Plains region.

2) could provide additional water-based recreation.

3) could supply water to the oil shale area of Colorado, which may eventually require an additional 2.5 million acre-feet annually.

Mexico:

1) could benefit from terminal spill into the Pecos River.

ALTERNATIVES

North Coastal California.

This area has some 12 million acre-feet of average annual discharge from

short coastal rivers. California is presently diverting 2.4 million acre-feet to Southern California, and it is estimated that the remainder will eventually be required locally.

The Lower Columbia River.

The average annual discharge at the mouth of the Columbia is approximately 165 million acre-feet. At present, this area has a large exportable surplus, but future growth will probably cancel out this surplus. The author suggests that Columbia basin states would not permit export unless assurance had been secured that British Columbia water could be imported when required.

James Bay Tributaries

It has been estimated that, by reversing the flow of streams feeding into James Bay and passing water through the lake system into the Mississippi River, approximately 36 million acre-feet could be made available for export. This scheme would probably require control works on the lake outlets to reduce the possibility of flooding during high precipitation years. Exported water would have to be withdrawn from the Mississippi River system to supply the seventeen western states.

The Lower Mississippi River.

Because the normal and minimal flows are fully utilized for navigation, water supply, and stream sanitation functions, any diversions would require capturing water during high flows. This would require large offstream storage capacity, which is difficult to obtain in the Lower Mississippi Valley. In addition, the water quality is deteriorating to the point where treatment would be required before further use could be made of the water. The author suggests that approximately 10 million acre-feet of storage could be created. Some 11 million acre-feet could be delivered to the High Plains area at a cost of $5.5 billion.

Atmospheric Water.

It has been reported that individual rainfalls might be increased by 10%. However, this would be effective only in areas which already receive significant amounts of water, such as high mountain regions. This technique could not be expected to deliver adequate amounts of water to desert areas.

Sea Water Desalting

Coastal areas of Southern California and of Texas will probably be supplied with water, at least cost, by desalination. Plans are underway by the Metropolitan Water District of Southern California to deliver 150 million gallons per day, or approximately 168,000 acre-feet per year, at an estimated cost of some $86 per acre-foot. This compares to $100 per acre-foot for Columbia water delivered to Los Angeles. Because of initial high costs, additional delivery costs soon render desalinated water uncompetitive at relatively short distances inland. Other complications are the large volumes of water required, and the lack of suitable building sites for plants along the California coast.

OBSERVATIONS AND COMMENTS

While this scheme is similar in concept to NAWAPA in the use of the Rocky Mountain Trench for conveyance of water, the major storage area is in the United States. The Prairie Water Exchange Concept is similar to Alberta's P.R.I.M.E. program in many instances, and to other proposals put foreword by various agencies.

The author suggests that British Columbia's claim to all her fresh water for all time is not as strong, economically, as is that of the Columbia basin states' claim to retaining Columbia water, because of climatic differences between the two regions. At another point, the author argues that a policy of encouraging people to migrate to where water is available, rather than allowing unchecked migration to water-short areas, should be adopted. It is also recognized

that any exports will be in perpetuity. This would be demanded because of the investment required in the conveyance system, and the lack of alternative sources.

IMPLEMENTATION PROBLEMS

1) Water transfer agreements in perpetuity would have to be negotiated.

2) Right-of-Way acquisition in areas already intensively developed would prove costly.

3) Many valuable spawning grounds of anadromous fish would be destroyed.

Sources: Western States Water Augmentation Concept by Lewis Gordy Smith.

Maps showing the Prairie Water Exchange Concept by Lewis Gordy Smith.

CANADIAN WATER EXPORT

by

E. Kuiper

THE PROBLEM

There is a definite water shortage in some areas of the United States. At the same time, there are many parts of Canada where water is available in such surplus quantities that, in all probability, it could never entirely be used by Canadians. A U.S. Senate Commission has looked at the possibility of water diversion on the North American continent, and feels the topic is worthy of further study. Kuiper has given this subject some consideration, and discusses, in rough figures, the feasibility of exporting Canadian water to the United States. He estimates the volume of water which could be exported without jeopardizing future Canadian development, the likely costs of various schemes, and the benefits which could accrue to Canadians if water diversion were to become a reality. His study-area is confined to the northern and western part of Canada.

PREDICTED TRENDS AND NEEDS

Kuiper concludes that the present water consumption of the approximately 3 million Canadians in the Prairie Provinces is about 2.5 million acre-feet per year. He estimates that a possible future population of 100 million in the region would require, as a maximum, about 80 million acre-feet of water annually.

TABLE IV

WATER AVAILABLE FOR DIVERSION

RIVER SYSTEM	AVERAGE ANNUAL FLOW (Millions of Acre-Feet)	AVERAGE ANNUAL FLOW AVAILABLE FOR DIVERSION (Millions of Acre-Feet)
Nelson	53	40
Churchill	20	15
Mackenzie	185	120
Yukon (at Alaska boundary)	55	55
TOTAL	313	230

In northwestern Canada, approximately 230 million acre-feet annually are available for diversion. Probably more than 100 million acre-feet of water per year actually could be exported to the United States.

THE PROPOSAL

To meet the future needs of the Prairie Provinces, Kuiper feels that approximately 60 million acre-feet per year could be diverted from the Lake Winnipeg area. In addition 10 million acre-feet could be obtained annually from the Peace River and 10 million acre-feet from the Athabasca River.

The general diversion route suggested would direct water from the Peace River via Lesser Slave Lake to the Athabasca and finally to the Saskatchewan River system. Additional water could be diverted to the Saskatchewan from the Churchill River via the Sturgeon-Wier River.

Water could then be distributed from the Saskatchewan River System to water-deficient areas in the Prairie Provinces.

To meet export requirements to the United States, Kuiper considers several possibilities which, in some combination, could comprise an overall water diversion scheme. For instance:

1) Water could be pumped from Lake Winnipeg, eventually into the Souris River, from which diversions could be made to the Great Plains region in the Midwest United States, and through a series of canals and reservoirs, to as far south as Texas.

2) Water could also be diverted from Lake Winnipeg via Rainy River into Lake Superior, and then at Chicago passed into the Des Plaines River and finally into the Mississippi River.

3) From the Yukon, Liard and Peace Rivers, water could be passed along the Rocky Mountain Trench to water-deficient areas in the American Southwest and northern Mexico.

Although these exportation schemes would involve constructing canals, tunnels, dikes and dams, pipelines and pumping stations, Kuiper feels that even today "none of the required works would fall outside the realm of present Civil Engineering technology."

Benefits

Providing water for the irrigation of presently underutilized land may be a major use of water diversion projects as food requirements increase in the United States.

By diverting water to underpopulated areas in the American Southwest, denser urban settlements could be developed in these regions, thus hopefully relieving urban congestion in more settled areas.

Canada might receive much higher returns from water by diverting it to the United States if water has a relatively low value use here. For instance, one acre-foot of water might produce one dollar's worth of hydro-electric power on the Nelson River. If this power were provided by some other means (coal or nuclear), Canada might obtain $20 per acre-foot by selling this water to the United States.

Cost

Although, for the Prairie Provinces alone, the yearly cost of such a diversion scheme is estimated at one billion dollars, Kuiper does not feel the cost would be prohibitive. For the predicted future population on a per capita basis, it would amount to about ten dollars per person each year. Eighty million acre-feet annually would thus be distributed throughout the Canadian prairies.

The diversion costs of water to various U.S. areas shown in the following table.

TABLE V

COST OF DIVERTING WATER ON AN ACRE-FOOT BASIS

PROPOSED DIVERSION ROUTE	AMOUNT OF WATER DIVERTED (Millions of ac.-ft./yr.)	PRICE AT BORDER ($/ac.-ft.)	PRICE AT DELIVERY ($/ac.-ft.)
1) Kootenay and Fraser Rivers to the southwest U.S.	20	30	70
2) Yukon River through Rocky Mountain trench to U.S.	100	20	60 - 70
3) Lake Winnipeg via Souris River to U.S.	40	25	35 - 75
4) James Bay tributaries via Lake Superior to U.S.	30	10	Not est.

While the price of water diversion to the U.S. may seem exorbitant today, Kuiper feels that, given a much larger population, with a higher standard of living and a greater demand for water, the cost may eventually fall well within the range of economic feasibility.

ALTERNATIVES

Desalination of sea water is one suggested alternative to water diversion in North America. When Kuiper wrote his article "Canadian Water Export", costs

ranged from $300 to $1,000 to desalinate one acre-foot of water. However, with an anticipated improvement in technology, the cost of the process may be reduced to $90 or even $50 per acre-foot. This, however, would not be the final cost of desalinated water. To the initial cost must be added the price of transferring the water to its use-area. An additional $20 per acre-foot would likely be required to transport the water perhaps 400 miles horizontally to a height of approximately 1,000 feet above sea level. When comparing desalination costs with delivery prices of diversion waters (see Table II), it can be seen that diversion will be, in the predictable future, a competitive method of providing water to water-deficient areas.

OBSERVATION AND COMMENTS

Before exporting water across international boundaries becomes a feasible process, it must be demonstrated that:

1) the country contemplating exportation has a definite water surplus in the forseeable future. Kuiper suggests that:

   a) the British Columbia-Yukon area plus the Prairie Provinces and adjacent Northwest Territories each have surpluses of approximately 100 million acre-feet per year;

   b) Northwestern Ontario has an additional 200 million acre-feet of water available for export each year.

2) The exporting country must receive a resource value for the exported water over and above payment of delivery costs, to provide an incentive for the country to export water;

3) through diversion, the country importing water must receive a net economic benefit after paying for the diverted water. This value should exceed that which could be obtained from the next best alternate scheme (such as desalination, diversion of surplus water from within that country or better treatment of available water to produce higher reuse capabilities).

Any water treaty between two countries must be flexible enough to allow for future adjustments to water demands, and must permit changes in the price of water and in the volume transferred to be renegotiable.

The treaty should be of sufficient duration to permit both parties involved to obtain the anticipated benefits from the diversion project.

There appears to be little possibility that the export of Canadian waters will become economically feasible in the near future.

However, because of the economic and political implications of water export, more detailed studies are justified.

Sources: Kuiper, E., "Canadian Water Export," The Engineering Journal. Vol. 49, No. 7. Toronto. Engineering Institute of Canada, July, 1966. pp. 13-18

Kuiper, E., "The feasibility of Water Export", paper presented to The Water Studies Institute, Saskatoon, Sask., Nov. 17, 1967.

The GRAND Canal Concept

by

T. W. Kierans

Kierans' GRAND Canal concept is, at this time, theoretical. It outlines a scheme which could regulate the level of water passing through the Great Lakes, maintaining the flow at a constant optimum level. Concurrently, this system could provide a new source of water for export to some of the water-deficient areas on the North American continent.

But again, it must be stressed that at the present time, this concept is only theoretical. No study has been conducted which would provide either a detailed cost-benefit analysis of the scheme or specific suggestions as to where or how many or what type of dams, channels and control points would be necessary to construct this water level-conditioning system.

THE PROBLEM

It is obvious, however, that a water supply problem exists today in the Great Lakes area. And the "steadily declining levels, flows and quality of these waters" will produce an even greater dilemma as population and industrialization increase in the region. Water levels on the Great Lakes fluctuate considerably during periods of drought and high precipitation. This situation can adversely affect water-users whether by diminishing their water supply needed for domestic, industrial, pollution-dilution, irrigation and other purposes, or, in the opposite extreme, by causing floods throughout the Great Lakes-St. Lawrence River system.

In the future, water demands are expected to intensify in both urban and rural areas. Higher water consumption in the upstream regions will create greater hardships for downstream users. In 35 years, the U.S. Department of Public Works predicts that, for the Great Lake states alone, a water deficiency of 35,000 c.f.s. for withdrawal purposes will exist.

THE PROPOSAL

Kierans outlines a system which he feels could alleviate this water supply problem. Since 80% of the water in the Great Lakes is discharged through Lakes Michigan and Huron, he feels that the key to maintaining an optimum flow of water throughout the entire Great Lakes system lies in stabilizing the water level in these two lakes. The processes involved in maintaining a stabilized flow can be shown in the following equation:

Total Volume of Water Entering Lakes Michigan and Huron from:		Total Volume of Water Leaving Lakes Huron and Michigan from:
a) inflow from Lake Superior		a) evaporation from the two lakes
b) precipitation on the two lakes	=	b) diversions from the lakes
c) inflow from other tributaries		c) natural discharge via the down-stream Great Lakes system.
d) groundwater inflows		

What Kierans proposes, therefore, is "a multi-purpose, continuously operating, water level-conditioning system". Acting on the same principle as an air-conditioning unit, this scheme could provide additional inflows of water during drought periods to these two lakes via constructed import channels from adjacent watersheds, and new channels for exporting water when excessive amounts are present. Both import and export channels would lead directly into or out from Lakes Michigan and Huron.

The major source for additional water in the system could be obtained from the James Bay watershed, thus making of the Bay, itself, a huge fresh water reservoir. Fresh water which is now more-or-less wasted could be diverted into the Great Lakes.

> "The rivers feeding James Bay would be dammed, and a series of pumps, powered by hydro-electric power, would lift a large portion of the rivers' flow upstream and over the 950 foot high East-West divide. From there the waters would flow south toward the Great Lakes. At the junction of the Ottawa and Mattawa Rivers most of the flow would be channelled into the Georgian Bay on the northern end of Lake Huron. But part of the flow would be sent down the Ottawa River to empty into

the St. Lawrence at Montreal."[1]

Kierans names this the Grand Replenishment and Northern Development (GRAND) Canal system.

1. Jay R. Bingham, "A Review of Inter-regional and International Water Transfer Proposals", Minutes of the Thirteenth Meeting. Las Vegas, Nevada, Western States Water Council, October, 1968 p. A-15.

Benefits

Although Kierans does not predict the cost of constructing and maintaining such a system, he does suggest several benefits which could be derived from it.

The volume of water passing through the Great Lakes system could be regu-ated, obtaining extra water from other watersheds when needed, or passing excess water through export channels during flood-danger times.

Water from the James Bay watershed could be exported on a permanent basis to water-deficient areas on the continent. Since this export system would be directly linked with the water-level conditioning system, the cost of the project could be spread over a larger use-area.

Since other adjacent rivers, such as the Ottawa River, could be incorporated into the system, these watersheds could receive the benefits of water level conditioning as well.

As the name of the proposed scheme implies, the system should provide growth and development possibilities in the James Bay area.

In addition, channels developed for the system could create new navigation routes, new sites for power development, and additional flood control sites.

ALTERNATES

The main alternative which Kierans suggests to his level-conditioning scheme is the "regulation only" principle, which is essentially a system of flood control and water rationing. It would involve storing water in times of flood, releasing extra water in periods of drought. There would be no means of obtaining

additional water if it were needed.

Constructing this type of system would require extensive and complex channel enlargements and restrictive works in the Detroit and St. Clair Rivers, as well as in areas further downstream towards Montreal. (In all probability these works would create obstructions to navigation.) Control of the channel slope would be of major importance in this scheme. Although the estimated cost of such a project is over one billion dollars, the U.S. Army Corps of Engineers feels the best plan under this system would "reduce the range of stage" in Lakes Michigan and Huron only from 5.6 to 4.2 feet.

This system's objectives would be to increase the Great Lakes' discharge capacity by as much as 3,000 c.f.s. above normal, if necessary.

When comparing the "regulation only" principle with the level-conditioning one, Kierans feels several disadvantages becomes apparent.

1) This scheme is not as flexible as the level-conditioning concept. For instance, "regulation only" could not be as easily expanded or altered if long term changes in water production in the area developed.

2) No new water source would be included in the system. For this reason, it would probably not be possible to:

   a) export water to water-deficient areas elsewhere on the continent, or

   b) keep a continual, optimum flow of water passing through the Great Lakes system over a long period of time.

3) Since the "regulation only" system would not incorporate tributary watersheds, such as the Ottawa River's, into the scheme, it could not effectively control the flow of these tributary rivers during long periods of drought or high precipitation.

4) For this reason too, this scheme would not instigate general growth and development in the James Bay hinterland, an important principle in the level-conditioning concept.

OBSERVATIONS AND COMMENTS

If the level-conditioning scheme is to function effectively, a system must be developed which can respond adequately and oppositely to natural water-level changes in Lakes Michigan and Huron, hopefully on a short-term, month-to-month basis. Therefore, an efficient and accurate data collection and analysis system is probably as necessary to the scheme as the actual construction of a well-designed physical plant.

Sources: T. W. Kierans, M.E.I.C., "The GRAND Canal Concept", The Engineering Journal, Vol 48, No. 12, Toronto, The Engineering Institute of Canada, December, 1965, pp. 39-42.

Jay R. Bingham, "A Review of Inter-regional and International Water Transfer Proposals", Minutes of the Thirteenth Meeting Las Vegas, Nevada, Western States Water Council, October 1, 1968, p. A-15.

THE CENTRAL NORTH AMERICAN WATER PROJECT

by

E. R. Tinney

THE PROBLEM

There is a definite water shortage in a large, U-shaped tract of land extending from the Western United States into Mexico. Large continental water diversion schemes have been propounded to alleviate this deficiency. Tinney suggests that these proposals do not adhere to a set of engineering objectives which he feels should be followed in such projects. These aims he lists as:

a) the utilization of as many natural features in the diversion system as possible.

b) at the same time, the use of as few artificial structures as possible; and

c) concurrently, the least possible disturbance of the natural environment utilized in the scheme.

THE PROPOSAL

Tinney proposes an alternate continental diversion project called CeNAWP- the Central North American Water Project, which follows his suggested principles and consists of four main parts areally.

1) The Canadian Central Water Supply System would transfer surplus Canadian water from the Mackenzie, Churchill, and Nelson Rivers along a route utilizing as many natural lakes as reservoirs as possible, in a more-or-less diagonal direction from Great Bear Lake to Lake Winnipeg. Because these various lakes are relatively closely spaced, only a few hundred miles of canals would be required to connect them into a water diversion system. The land is generally flat along this route and therefore fairly conducive to canal construction

2) a Central American Canal

3) a Southwest American Canal; and

4) a North Mexico Development.

These latter three proposals in CeNAWP involve transporting water from Lake Winnipeg, through central North America to the water deficient southwestern states, and into Mexico. Although a great deal of canal construction would be necessary, a very direct water route to supply areas would thus be attained. Where possible natural river courses would be utilized - along part of the Missouri River in the northern states, and in the Southwest into the Colorado and Rio Grande Rivers which could transport water into Mexico. These American canals could provide an initial internal water diversion scheme within the United States, connecting the water-deficient Southwest with the Missouri-Mississippi River system. A scheme supplying Canadian waters to the project would not, in all probability, be required at first.

Benefits

While Tinney does not suggest the cost of CeNAWP in his article, he does propose some of the benefits which could be derived from it.

CeNAWP would supply water to arid areas in the American Southwest and Mexico, at the same time providing Canada with a saleable resource for export.

The series of canals linking the various lakes in the northwestern Canadian diversion route would provide an extensive waterway for summer barge traffic, which would extend from Lake Winnipeg to the Arctic Circle.

New hydro-electric power sites could be developed along this system.

A canal linking Lake Winnipeg with the Great Lakes could supply additional water to this latter area to maintain water elevations in the Great Lakes at an optimum level.

With the extension of greater control over the waters in the rivers of northwestern Canada, low-lying, marshy lands which are now periodically flooded could be reclaimed.

ALTERNATIVES

If one of the main reasons for diverting water is to supply arid regions with water for irrigation, it might be possible instead to supply water to a greater percentage of unirrigated land in watersheds which presently have a water surplus. Thus a major reason for diverting water in the first place would be alleviated. (For example, within the Columbia River watershed alone, there is a probable additional 25 million acres of land which could be irrigated.)

Providing arid areas with desalinated water, coupled with a supply of brackish water for use where possible, plus the enforcement of stringent pollution controls, could possibly supply these regions with water in sufficient quantities to eliminate the need for water diversion.

Internal water diversion within the United States, (for example, directing water from the Mississippi River across 700 miles of plains to the Texas Panhandle), might be an alternative.

Weather modification might produce sufficient precipitation to arid areas to alleviate the necessity of water diversion.

Other continental water diversion schemes such as NAWAPA are also possible, although Tinney feels this particular scheme is "cumbersome and awkward", and also undesirable because it does not follow his advocated engineering principles, outlined earlier in this report.

OBSERVATIONS

In order to determine whether a diversion scheme is feasible and desirable,

two steps in its planning stage should be followed.

1) The problem or development opportunity should be defined.

2) Existing and potential demands for water in the study-area should be ascertained to determine whether the diversion scheme would be necessary.

Other proposals for supplying water to deficient areas should be carefully examined, including cost-benefit analyses of these alternatives.

Once the first three steps are adequately researched, the most appropriate solution should be adopted. In so doing, not only economic aspects of the scheme should be taken into consideration, but also the less tangible, social aims should play a part in determining the final project choice.

Continental water diversion schemes should be accepted as feasible. In fact, one day such schemes may be inaugurated simply to create new sources of employment, or to open up new territories for development.

Source: E. Roy Tinney, "Engineering Aspects", Bulletin of the Atomic Scientist, Vol. 23, No. 7, September, 1967, pp. 21-25.

PROPOSED GREAT LAKES-PACIFIC WATERWAYS PLAN

by

Ivan Decker
August 1963

THE PROBLEM

To provide water-borne transportation, a navigable waterway from the Pacific Ocean to the Great Lakes is required. As well, water could be provided for irrigation in Saskatchewan and the Dakotas and for power generation on the Missouri.

PREDICTED TRENDS AND NEEDS

None available

THE PROPOSAL

Decker proposes that a navigable waterway could be constructed over the Canadian Cordillera.

Tide water on the Pacific would be at Prince Rupert. A series of lift locks on the Skeena River would raise vessels vertically 850 feet. From here, a rail mounted shipping lift would transport vessels to the crest of the Coast Range. Another series of lift locks would move vessels to the Nichako River, which flows into the Rocky Mountain Trench.

The Nichako and Fraser Rivers would be diverted into the Peace River, via the Parsnip River. To provide additional flows in the waterway, the Liard River could be diverted to the Peace River by means of a 1,000+ foot high dam and a 50 mile long tunnel. The Peace River would be diverted to the Athabasca River via a canal through Lesser Slave Lake. The waterway would continue eastward by diversion of the Athabasca to the North Saskatchewan; the diversion of the North and South Saskatchewan Rivers to the Qu'Appelle River; and diversion of the Qu'Appelle to the Souris River. The flow of the Souris would be reversed by means of a large dam, to effect distribution to the Missouri River and to irrigable areas in the Dakotas. The waterway also would use the Souris Reservoir,

and then by a series of canals and river channels, terminate at Lake Superior.

Costs

Not available

Benefits

The proposed water yields are shown in Table VI.

TABLE VI

PROPOSED WATER YIELD

DIVERSION	WATER YIELD Ac.-Ft./Year
Skeena & Babine to Nichako	15,000,000
Liard to Peace	25,000,000
Nichako & Fraser to Peace	30,000,000
Peace to Athabasca	41,000,000
Athabasca to North Saskatchewan	11,000,000
North and South Saskatchewan to Qu'Appelle	18,000,000
TOTAL	140,000,000

OBSERVATIONS AND COMMENTS

The propounded Great Lakes-Pacific Waterways Plan has several proposals similar to other diversion schemes. These include:

1) diversion of the Liard River via the Kechika and Finlay Rivers into the Peace River.

2) diversion of the Peace River into the Athabasca River via Lesser Slave Lake.

3) diversion of the North and South Saskatchewan Rivers via the Qu'Appelle River.

4) diversion from the Souris River into the Missouri River system.

IMPLEMENTATION PROBLEMS

Studies would be required to determine the engineering and the economic feasibility of constructing and maintaining the proposed fresh water navigation channel.

The question of committing water to navigation use, which has a low priority rating, would have to be examined critically.

Treaties governing the interprovincial and international transfer of water would have to be negotiated.

Source: A copy of an outline map prepared by Ivan Decker, August 1963.

THE MAGNUM CANAL

by

K. Magnusson

March, 1967

THE PROBLEM

To divert surplus Canadian water to the United States Midwest.

PREDICTED TRENDS AND NEEDS

Not available.

THE PROPOSAL

To deliver to water-deficient areas the equivalent of the volume of one Missouri River immediately, and another one by the year 2,000. The Magnum Scheme contains the following proposals:

1) Diversion of the Liard River southward into the Peace River.
2) Storage in the existing Peace River Reservoir would be utilized.
3) Diversion from the Peace River to the Lesser Slave Lake via canal.
4) Storage areas would be created on the Smoky River.
5) Water from the Smoky River would be diverted by canal to Lesser Slave Lake
6) Storage capacities would be increased on Lesser Slave Lake by raising the F.S.L. 20 to 40 feet above the natural surface elevation.
7) Water from the Athabasca River would be collected in the Lesser Slave Lake Reservoir.

8) Water from the Lesser Slave Reservoir would be diverted by canal southeastward. The canal would cross the North Saskatchewan, the South Saskatchewan, and the Qu'Appelle Rivers to the Souris River.

9) The Magnum Canal would divert water from the Souris River in North Dakota southward into the Missouri River.

10) Water would be diverted from the Missouri in the vicinity of Sioux City, Iowa and distributed by canal to several mid-western states.

Costs

Not available

Benefits

Local irrigation projects could be serviced by the Magnum Canal.

The Canal would permit development of thermal power plants at the Estevan coal deposits.

The South Saskatchewan dam would benefit from additional power generation.

A yearly capital outlay for the Magnum Canal of one billion dollars during construction, benefiting the Canadian economy.

ALTERNATIVES

An alternative would be the Kuiper Scheme, which would provide the equivalent volume of five Missouri Rivers at the same diversion point on the Souris River. However, Magnusson suggests that the Kuiper Scheme could not be implemented until cheap fusion nuclear power becomes available.

The Magnum Canal could be implemented now, to be replaced by the Kuiper Scheme when Canada needs additional water.

OBSERVATIONS AND COMMENTS

The Magnum Scheme appears to depend upon the Liard River system as the major source of supply. The probable effects of diversion from this system would require study.

The raising of Lesser Slave Lake to an F.S.L. of between 2,000 feet and 2,020 feet above sea level would flood a considerable area.

Water from the North Saskatchewan, Red Deer, and South Saskatchewan Rivers would seem to be slated for export.

IMPLEMENTATION PROBLEMS

Implementation problems would be similar to other interprovincial and international water transfer proposals.

Source: A copy of the map showing the Magnum Canal, prepared by Knut Magnusson. Several pamphlets submitted by Knut Magnusson, including:

Should Water in Western Canada be Exported to U.S.A.?, November 20, 1965; revised 2nd edition, January 13, 1966.

Atlin Lake - Skagway Project, July 8, 1966.

Magnum Canal Extension in U.S.A., July 25, 1966.

An Evaluation of PRIME in Its Connection with the Magnum Canal Concept, October 1, 1966.

Does Canada have Surplus Water When there is Drought in the U.S.A. Midwest?, February 23, 1967.

When Should Canada Export Prairie Water to the U.S.A.?, A comparison between the Kuiper plan and the Magnum plan, February 24, 1967.

Water for Sale, A Canadian Dilemma, November 6, 1967

SUMMARY

Interest in the diversion of water from areas in Canada with supplies judged to be surplus to local needs has a relatively long history. The concept of diverting Prairie rivers from their natural courses onto the semi-arid uplands occured to several early pioneers. One proponent of this concept, Wm. Pearce, suggested as early as 1919 that water from the Red Deer River be diverted to East-Central Alberta to provide a supplemental water supply. An early proponent of international transfers was M. King Hubbert, Special Assistant to Harold Ickes, Secretary of the Interior in the United States during the 1930's. Mr. Hubbert proposed the transfer of waters southward via the Rocky Mountain Trench.

The continued interest in transferring water from Northern Canada to areas with actual or potential water shortages is evident from the number of proposals summarized above. Other proposals and concepts, such as Alberta's PRIME program are under study or discussion. Continued dialogue and debate on the need for diversion, the means of delivery, and the implications of water export can be expected.

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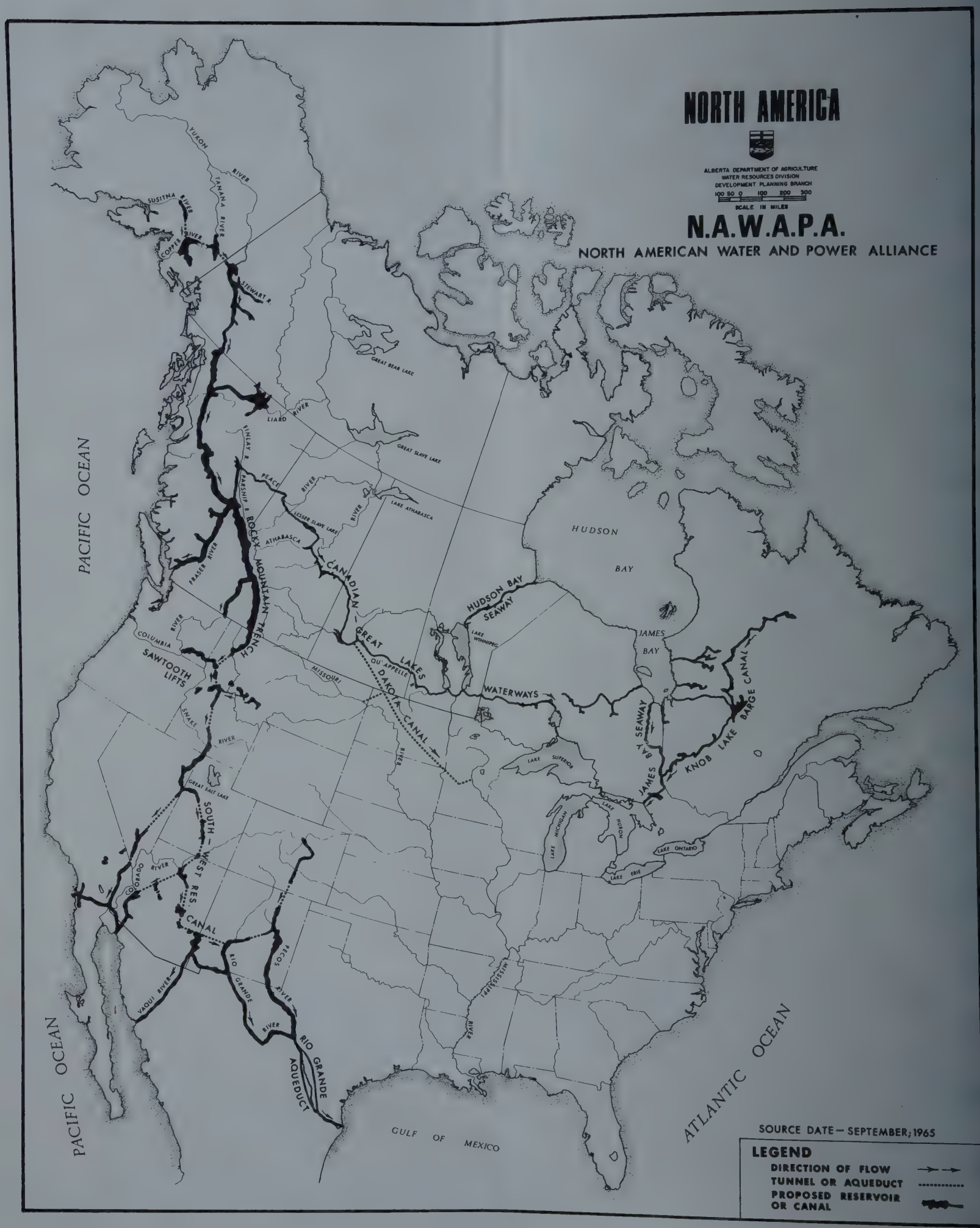
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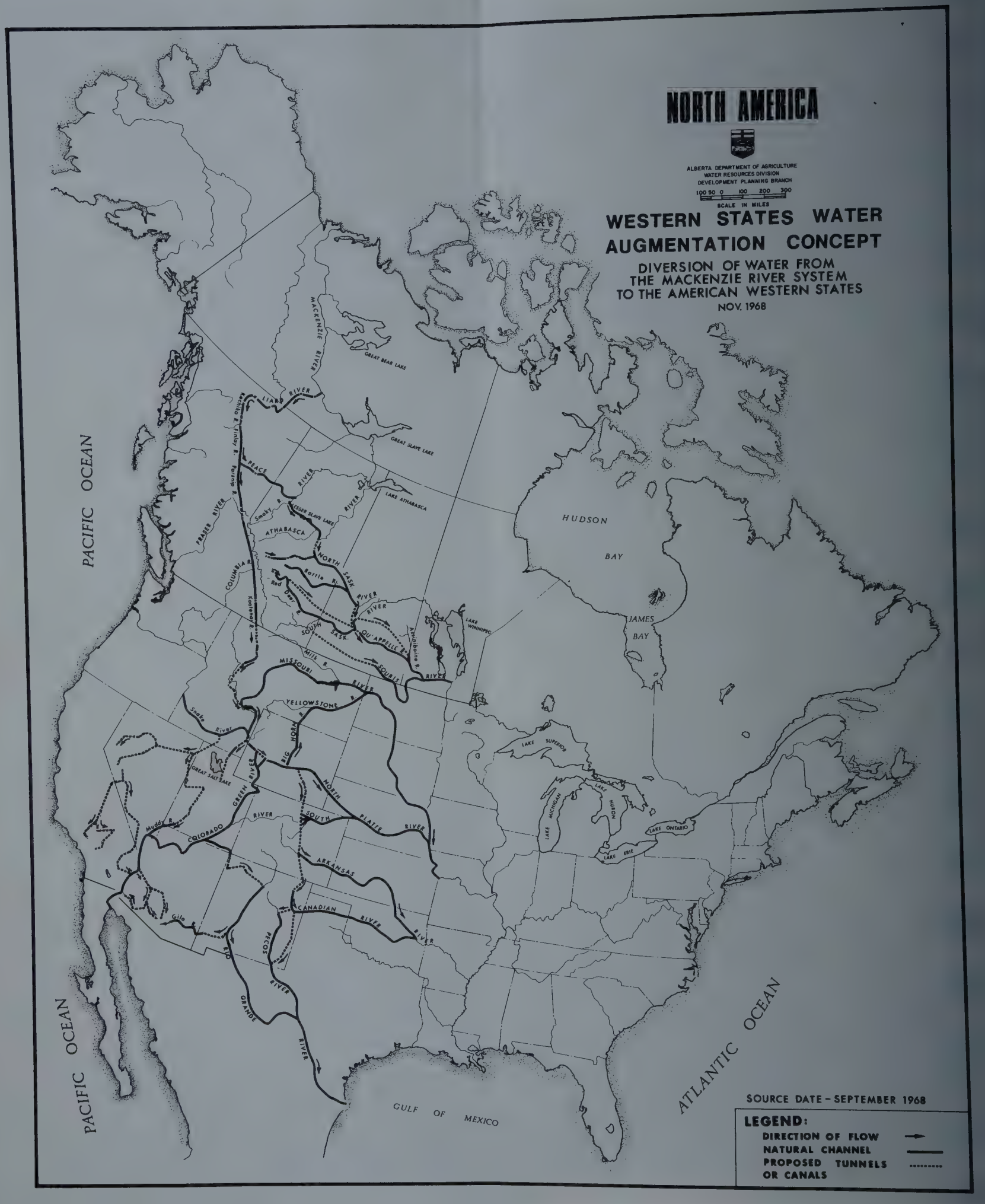
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NORTH AMERICA
ALBERTA DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH
100 50 0 100 200 300
SCALE IN MILES
N.A.W.A.P.A.
NORTH AMERICAN WATER AND POWER ALLIANCE
PACIFIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
HUDSON BAY
JAMES BAY
YUKON RIVER
TANANA RIVER
SUSITNA RIVER
COPPER RIVER
STEWART R.
GREAT BEAR LAKE
LIARD RIVER
GREAT SLAVE LAKE
FINLAY R.
PARSNIP R.
PEACE RIVER
LESSER SLAVE LAKE
LAKE ATHABASCA
ATHABASCA RIVER
FRASER RIVER
COLUMBIA RIVER
ROCKY MOUNTAIN TRENCH
SAWTOOTH LIFTS
SNAKE RIVER
GREAT SALT LAKE
COLORADO RIVER
SOUTH-WEST RES. CANAL
VAQUI RIVER
RIO GRANDE RIVER
PECOS RIVER
RIO GRANDE AQUEDUCT
CANADIAN-GREAT LAKES WATERWAYS
HUDSON BAY SEAWAY
LAKE WINNIPEG
OU APPELLE
MISSOURI
DAKOTA CANAL
MISSISSIPPI RIVER
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
JAMES BAY SEAWAY
KNOB LAKE BARGE CANAL
SOURCE DATE — SEPTEMBER; 1965
LEGEND
DIRECTION OF FLOW
TUNNEL OR AQUEDUCT
PROPOSED RESERVOIR OR CANAL


NORTH AMERICA
ALBERTA DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH
100 50 0 100 200 300
SCALE IN MILES
WESTERN STATES WATER AUGMENTATION CONCEPT
DIVERSION OF WATER FROM THE MACKENZIE RIVER SYSTEM TO THE AMERICAN WESTERN STATES
NOV. 1968
PACIFIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
HUDSON BAY
JAMES BAY
MACKENZIE RIVER
GREAT BEAR LAKE
LIARD RIVER
GREAT SLAVE LAKE
PEACE RIVER
FRASER RIVER
COLUMBIA R.
LAKE ATHABASCA
ATHABASCA
NORTH SASK. RIVER
SOUTH SASK. RIVER
QU'APPELLE R.
LAKE WINNIPEG
MISSOURI RIVER
YELLOWSTONE R.
BIG HORN R.
SNAKE RIVER
GREAT SALT LAKE
GREEN RIVER
COLORADO RIVER
NORTH PLATTE RIVER
SOUTH PLATTE RIVER
ARKANSAS
CANADIAN RIVER
PECOS RIVER
RIO GRANDE RIVER
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
SOURCE DATE - SEPTEMBER 1968
LEGEND:
DIRECTION OF FLOW
NATURAL CHANNEL
PROPOSED TUNNELS OR CANALS

DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH

CANADA

100 50 0 100 200
SCALE IN MILES

KUIPER DIVERSION SCHEME

DIVERSION OF WATER FROM LAKE ATHABASCA
TO THE MISSOURI RIVER SYSTEM
NOVEMBER, 1968

BEAUFORT SEA

GREAT BEAR LAKE

GREAT SLAVE LAKE

LAKE ATHABASCA

Fond du Lac

Wollaston Lake

Reindeer Lake

Churchill River

Amisk L.

SASKATCHEWAN

Cedar

Grand Rapids

Lake Manitoba

LAKE WINNIPEG

HUDSON BAY

JAMES BAY

LABRADOR SEA

GULF OF ST. LAWRENCE

LAKE SUPERIOR

LAKE MICHIGAN

LAKE HURON

LAKE ERIE

LAKE ONTARIO

PACIFIC OCEAN

ATLANTIC OCEAN

LEGEND
DIRECTION OF FLOW —→
PROPOSED CANAL ———
NATURAL CHANNEL — — ·····

SOURCE DATE: JULY, 1966

DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH

CANADA

100 50 0 100 200
SCALE IN MILES

KIERANS DIVERSION SCHEME

ALBANY RIVER TO LAKE HURON
SCHEMATIC DIAGRAM

NOV. 1968

BEAUFORT SEA

GREAT BEAR LAKE

GREAT SLAVE LAKE

LAKE ATHABASCA

LAKE WINNIPEG

HUDSON BAY

JAMES BAY

LABRADOR SEA

GULF OF ST. LAWRENCE

PACIFIC OCEAN

ATLANTIC OCEAN

ALBANY RIVER

Ogoki

Kenogami

Missinaibi

Kapuskasing

Mattagami

Abitibi

Matabitchuan

Ottawa

Lake Nipissing

LAKE SUPERIOR

LAKE MICHIGAN

LAKE HURON

St. Clair R.

Detroit R.

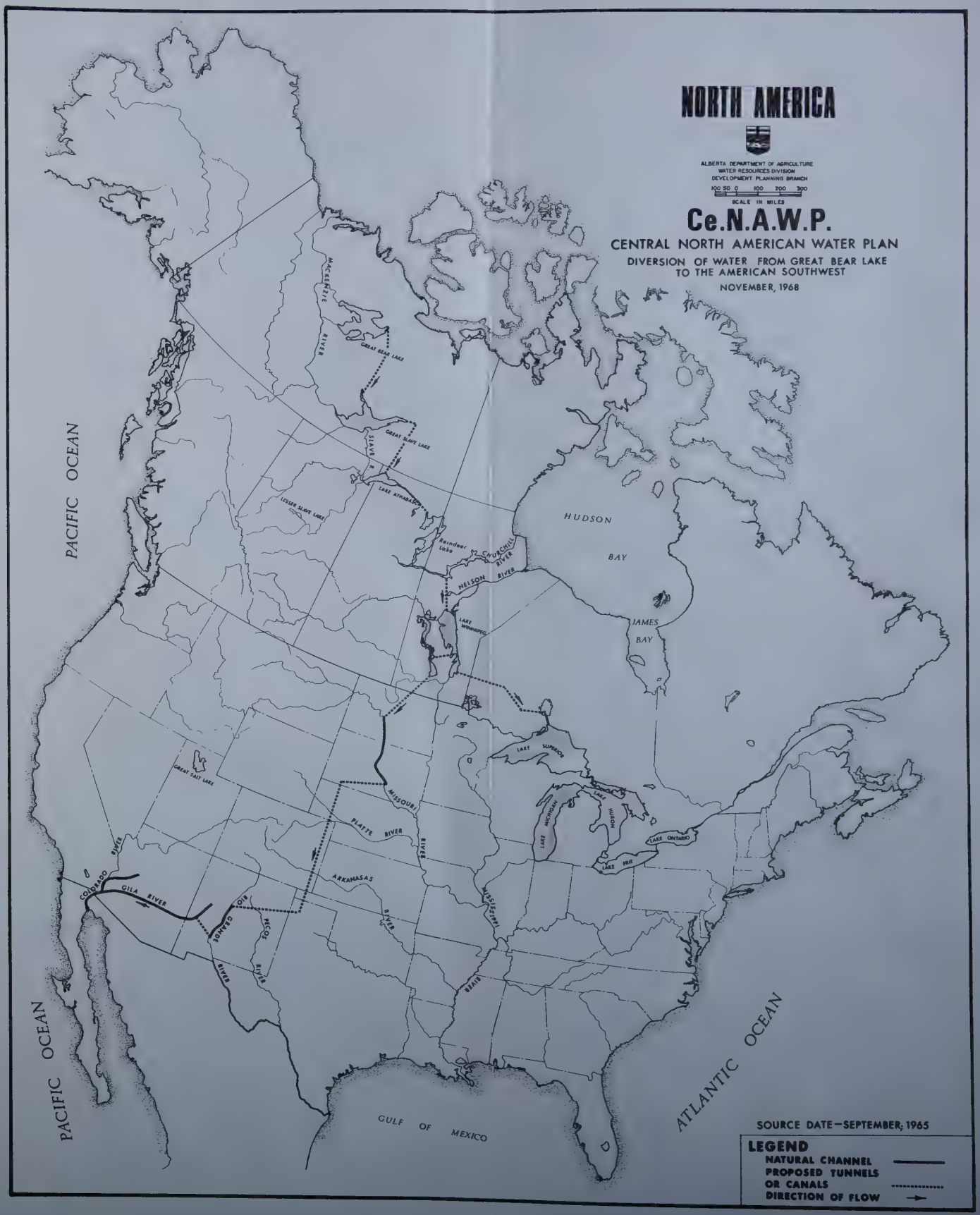
LAKE ERIE

LAKE ONTARIO

LEGEND

PROPOSED DAM
NATURAL CHANNEL
PROPOSED CANAL
DIRECTION OF FLOW

SOURCE DATE – DECEMBER 1968


NORTH AMERICA
ALBERTA DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH
100 50 0 100 200 300
SCALE IN MILES
Ce.N.A.W.P.
CENTRAL NORTH AMERICAN WATER PLAN
DIVERSION OF WATER FROM GREAT BEAR LAKE
TO THE AMERICAN SOUTHWEST
NOVEMBER, 1968
PACIFIC OCEAN
MACKENZIE RIVER
GREAT BEAR LAKE
GREAT SLAVE LAKE
PEACE RIVER
LESSER SLAVE LAKE
LAKE ATHABASCA
Reindeer Lake
CHURCHILL RIVER
NELSON RIVER
LAKE WINNIPEG
HUDSON BAY
JAMES BAY
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
GREAT SALT LAKE
MISSOURI RIVER
PLATTE RIVER
ARKANSAS RIVER
COLORADO RIVER
GILA RIVER
RIO GRANDE
PECOS RIVER
MISSISSIPPI RIVER
PACIFIC OCEAN
GULF OF MEXICO
ATLANTIC OCEAN
SOURCE DATE—SEPTEMBER, 1965
LEGEND
NATURAL CHANNEL
PROPOSED TUNNELS OR CANALS
DIRECTION OF FLOW

DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH

CANADA

100 50 0 100 200
SCALE IN MILES

DECKER DIVERSION SCHEME

GREAT LAKES – PACIFIC
WATERWAYS PLAN

NOV. 1968

BEAUFORT SEA

GREAT BEAR LAKE

GREAT SLAVE LAKE

LAKE ATHABASCA

HUDSON BAY

JAMES BAY

LAKE WINNIPEG

LABRADOR SEA

GULF OF ST. LAWRENCE

PACIFIC OCEAN

ATLANTIC OCEAN

Fraser R.
Nechako R.
Stuart R.
Bulkley R.
Skeena R.
Finlay R.
Omineca R.
Parsnip R.
PEACE RIVER
Lesser Slave Lake
ATHABASCA RIVER
Lac La Biche
NORTH SASKATCHEWAN RIVER
SOUTH SASKATCHEWAN RIVER
Last Mountain Lake
Qu'Appelle R.
Assiniboine R.
Souris R.
Moose Jaw R.
MISSOURI
Garrison Dam
Cheyenne R.
Oahe Dam
Big Bend Dam
Ft Randall Dam
Gavins Point Dam
Minnesota R.
Mississippi R.
St Croix R.
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE

LEGEND

PROPOSED DAM and or LOCK — ▸
NATURAL CHANNEL — —
PROPOSED CANALS or TUNNELS — ····
DIRECTION OF FLOW — →

SOURCE DATE – AUGUST 1963

DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
DEVELOPMENT PLANNING BRANCH

CANADA

100 50 0 100 200
SCALE IN MILES

MAGNUM DIVERSION SCHEME

DIVERSION OF WATER FROM THE PEACE RIVER
TO THE MISSOURI RIVER SYSTEM
NOV. 1968

BEAUFORT SEA

GREAT BEAR LAKE

GREAT SLAVE LAKE

LAKE ATHABASCA

PACIFIC OCEAN

HUDSON BAY

JAMES BAY

LABRADOR SEA

ATLANTIC OCEAN

GULF OF ST. LAWRENCE

LAKE WINNIPEG

LAKE SUPERIOR

LAKE MICHIGAN

LAKE HURON

LAKE ERIE

LAKE ONTARIO

PEACE RIVER

Lesser Slave Lake

ATHABASCA RIVER

Mcleod R.

Pembina R.

NORTH SASKATCHEWAN RIVER

RED DEER RIVER

Battle R.

SOUTH SASKATCHEWAN RIVER

QU'Appelle R.

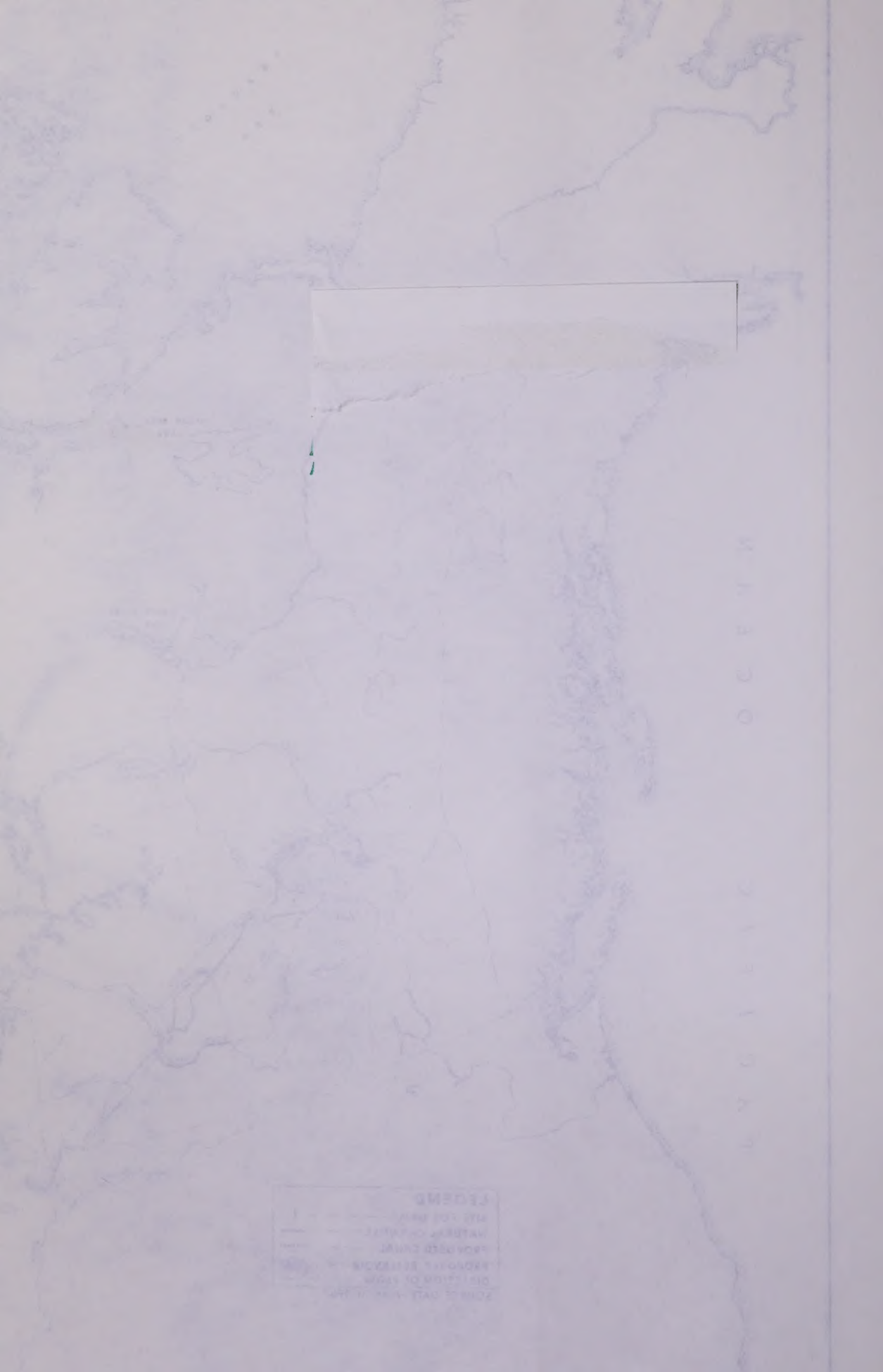
Souris River

MISSOURI RIVER

LEGEND

SITE FOR DAM
NATURAL CHANNEL
PROPOSED CANAL
PROPOSED RESERVOIR
DIRECTION OF FLOW

SOURCE DATE-MARCH 1967



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